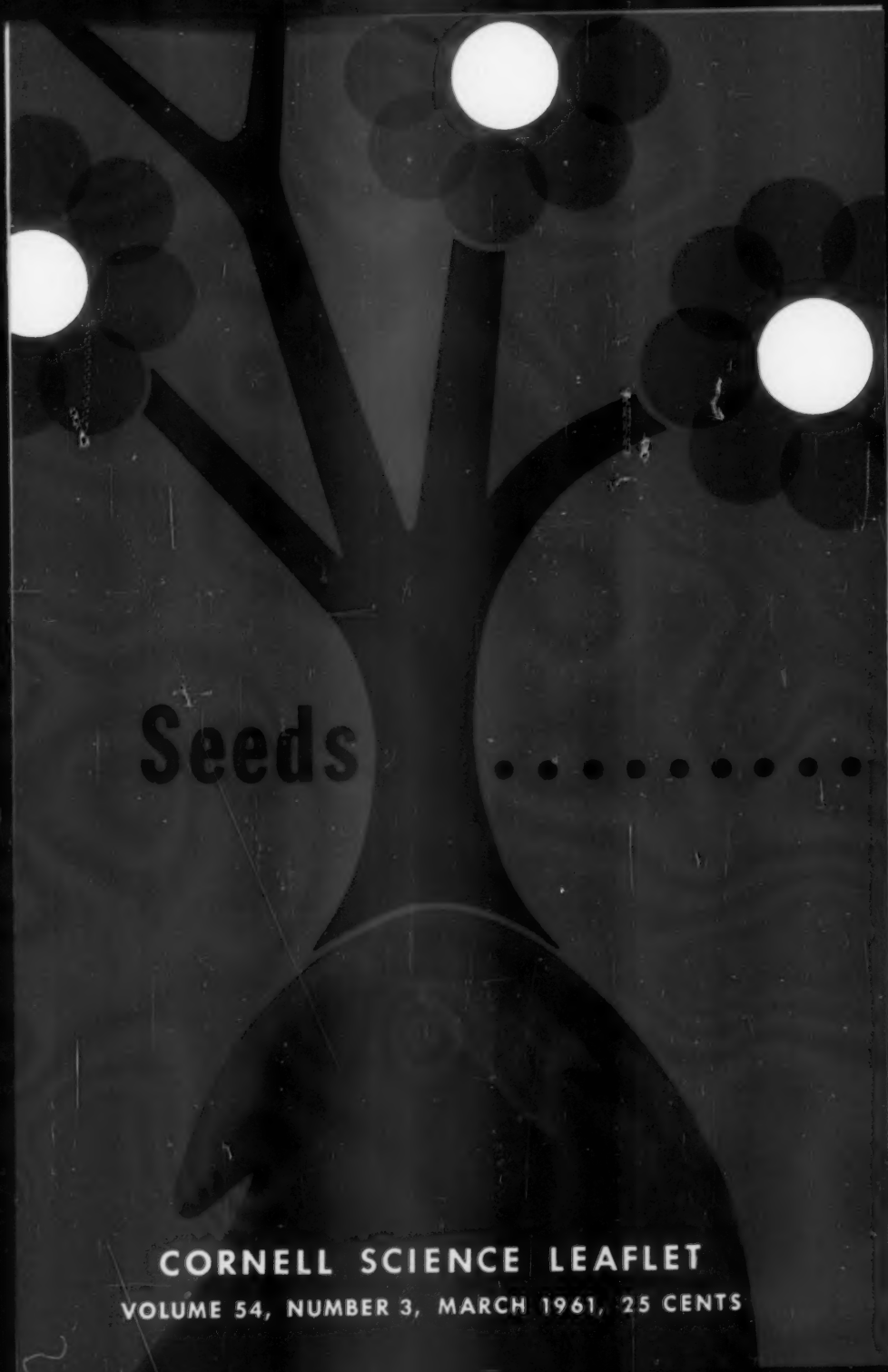



CORNELL SCIENCE LEAFLET
VOLUME 54, NUMBER 3, MARCH 1961, 25 CENTS

**CORNELL SCIENCE LEAFLET**
**Volume 54, Number 3, 25 cents, March 1961**

*Second-class postage paid at Ithaca, New York*

# Seeds

VERNE N. ROCKCASTLE

Where do seeds come from?
How do seeds travel?
Do all plants have seeds?
Can seeds sprout if they don't have soil?
Why won't seeds grow inside you if you eat them?
How old can seeds be and still sprout?
Can seeds freeze to death?
Why do some plants have many seeds while others have only a few?

These are some of the questions that children ask when they begin to study seeds. Perhaps these or other questions have been raised by children in your classes. If so, this Leaflet may help to answer some of them.

## WHERE DO SEEDS COME FROM?

All seeds come from flowers and nearly all flowering plants produce seeds. To understand how they are formed you must first understand the parts of a flower. The lily family is good to begin with; some of its representatives are the tulip, the Easter lily, the tiger lily, the trout lily (often called adder's tongue), the trillium, and the lily-of-the-valley. The daffodil and the narcissus are closely related, and also show the parts of a simple flower.

### The pistil

Look into the very center of a lily or one of its relatives. Can you see a slender green structure that stands straight up? In lilies it is usually split into three curled parts at its tip. This central structure with its swollen green base is called the *pistil*. It is the female part of the flower. The seeds are formed in the base of the pistil.

Cut through the swollen base of the pistil and you will see one or more compartments (usually three in the lilies) with little white structures resembling seeds in them. This enlarged base of the pistil is the *ovary*. The little white structures inside it are seeds in an early stage of development. When they are too young to be called seeds, they are called *ovules*. Some plants have only one ovule in each ovary, and some have many. Each ovule that matures becomes a seed. How many ovules do you think there would be in the ovary of a water-

**The three-lobed stigma and five of its six stamens are clearly visible in this Easter lily. Where would you look for the ovary in a lily?**

melon blossom? How many would there be in a peach blossom, or a cherry blossom?

The tip of the pistil is called the *stigma*. This is a very important part of the flower, because seeds can be formed only when the stigma catches and holds grains of pollen.

The stigma of each kind of flower has its own peculiar shape and special means of catching and holding the pollen that touches it. The usual three-part stigma of the lilies has a rough, sticky upper surface. In the may-apple, the stigma is ruffled like the bottom of a fancy petticoat. In the grasses such as timothy, the stigma has many fine projections like a bottle brush which give it more surface for catching wind-

borne pollen. Look at a number of flowering plants to see how varied and specialized the stigmas are.

A stigma may catch several kinds of pollen, but only pollen from the same plant species will help make seeds. The wind does not distinguish between the many kinds of pollen; it blows them all along. Insects may visit several kinds of flowers on the same day, although they fly from one flower to another of the same species for short intervals. They may leave more than one kind of pollen as they brush against the stigma. The chemical reaction that lets a pollen grain know when it is on the right stigma is still a mystery to scientists.

## The stamens

Around the pistil of most flowers are the *stamens* or male flower parts. Usually, there are several stamens for each pistil in a blossom. These structures resemble little knobs atop slender filaments. The knob-like part is called an *anther*. It produces the pollen that the wind or insects carry to the stigma.

The filament that supports the anther is so slender and shaky that the slightest breeze usually will make the stamen tremble. This serves to shake ripe pollen out of the anther whenever a breeze or an insect disturbs it.

On mornings in summer when there seems to be no wind at all, look at the stamens that stick out of a grass such as timothy. You will see the stamens trembling just as if you had breathed on them in spite of yourself. If they shake like this when there seems to be no air in motion, think how they must vibrate when a real breeze is blowing!

Each anther in a flower produces many, many pollen grains—too many to count. Together, the stamens of all the flowers on a single tree shake millions upon millions of pollen grains into the air. The swarms of bees that visit apple blossoms in an orchard also brush off untold numbers of pollen grains, most of which never find their way to the stigma of a flower.

Some stamens are almost completely enclosed in the flower and the wind does not affect them at all. A few such stamens deposit their pollen right on the stigma without the help of either wind or insects. Flowers of tobacco, oats, peas and cotton are usually pollinated before the blossom even opens.

Small bees sometimes cut right through the petals of flowers, including some that are closed, to reach the nectar at the base of the ovary. While buzzing and crawling around inside the blossom, they probably give the stigma a good dusting with its own pollen, and with some from other flowers.

The flower of the alfalfa plant, and of barberry, has a mechanism that pops the stamens against an insect's body when it disturbs the flower parts. This insures the insect's

Hundreds of white stamens clothe these heads of timothy.

Some of these sugar maple flowers have only stamens; some have only pistils. Can you see which are which?

getting a good dusting of pollen before it can leave the flower and visit another of the same kind. When it enters the next flower, it must brush past the stigma and leave some pollen there.

A few flowers such as the dandelion have stamens, but the pollen produced in them is not needed to produce seeds. In most flowers, however, pollen is an essential part of the seed-making process.

## Fertilization

A pollen grain is not like the rest of the cells of a flowering plant. Each pollen grain has only half the material it needs to be like the cells of the mature plant. Pollen grains could not develop into plants no matter how well they were cared for.

The egg cell in each ovule also has only half of what it needs to be like the cells in the rest of the plant.

With the exception of plants such as the dandelion, an egg cell cannot become a new plant until it combines with the sperm nucleus in a pollen grain.

When a pollen grain of the same species lands on a stigma, a curious thing happens: The pollen grain grows a microscopic tube right down through the pistil, through the wall of the ovary, and into the ovule. Through this pollen tube travel a sperm nucleus and some other nuclei. *Fertilization,* the process that really begins a new plant, occurs when the sperm nucleus unites with the egg cell.

The pollen tube through which a sperm nucleus travels is an amazing structure. So thin and tiny that a human hair looks huge by comparison, it is able to burrow its way through the pistil all the way to the ovule. Hundreds of pollen tubes must grow through the pistil of a single watermelon flower, because one pollen grain is needed to form each seed you find in a ripe melon. In the pistil of corn, a pollen grain must grow its tube down through a whole corn silk to reach the ovule. Its pollen tube must be several inches long to reach the ovules that become the bottom kernels or seeds of the corn. As you examine flowers of different kinds, notice the distance from stigma to ovary, and see how far the pollen tube must grow for the sperm to fertilize the egg.

Some flowers have more than one pistil in blossom or flower head. In the dandelion, each petal-like part of the blossom is a complete flower with its own pistil. If you look carefully, you can see the two-part stigma curling out of each yellow flower or floret. By pinching the whole dandelion blossom in two, you can see the white ovary at the base of each tiny floret, and the slender, two-part stigma projecting above it. There are many plants whose blossoms have numerous florets, each with its own pistil. The thistle, burdock, sunflower, chrysanthemum, and aster belong to the composite family, all of whose flowers contain numerous small florets which resemble miniature bouquets. How many other floral arrangements can you discover?

## The embryo

The fertilized egg soon divides into two cells, each just like the original fertilized egg. These two cells divide again and again to form four, eight, sixteen cells, and so on. Soon there is a whole cluster of tiny cells within the ovule. This little cluster of cells, called an *embryo,* is an entirely new plant. It is completely separate from the parent plants that made the sperm and the egg. If the embryo were to keep growing, it would develop roots, a stem, leaves, and finally flowers just as its parents did. However, nearly all plant embryos have their growth interrupted, as you will see.

## The ripening fruit

As changes take place in the embryo, changes also take place in the flower around it. The stamens wither and drop away; the stigma withers; the petals fall; and even the sepals around and below the petals wither or fall away. The ovary, however, usually grows in size, and often changes in firmness and color.

Some ripening ovaries become swollen and soft, and turn brilliant red (cherries). Some grow still larger and become fuzzy on the outside (peaches). Some become hard and yellow, and develop spines all over the outside (horsechestnut). One ovary pushes its way underground where it becomes brittle and straw-colored. You must dig it up and break it open to eat the seeds inside (peanuts). How many other changes can you find in ripening ovaries? Do you eat the ovary or the ripened ovules (seeds) of the watermelon, the cucumber, and the tomato? Do you eat the ovary or the seeds of the apricot and the plum?

In a few plants, such as the apple, the ovary remains thin-walled, but becomes very hard and shiny. Inside the seeds develop; outside, the base of the flower swells until it completely encloses the ovary. When you eat an apple, you do not eat the ovary. You eat some of the receptacle or flower stem that swells around the ovary. The ovary is the shiny part of the core, usually with the seeds inside.

In stringbeans, you eat both ovary and seeds. In peas, you usually eat only the seeds. In beans you eat the seeds. In the strawberry, however, you eat the receptacle (the large, red part) *and* the ovaries, each with its single seed, that stick to the outside. In strawberries, you can even see the remains of the pistil as a little hair that sticks up from each ovary. Can you find out what the little green leaves are that you must pick off before you eat your strawberry?

## The cotyledons

As the ovary or the receptacle ripens, the seeds inside are also becoming mature. The embryo begins to show signs of leaves and a root, and makes increasing demands on the stored food around it.

While the embryo was in its early stages of development, the rest of the ovule produced a mass of starchy food material called *endosperm*. Starch is one of the basic food materials manufactured by the parent plant, but it is not often in the form that is best used by a developing embryo. So the embryo forms one or two seed leaves that absorb and digest the starch and in turn feed the embryo itself. These seed leaves or *cotyledons* use up all the starchy endosperm in some seeds, even before the seed is ripe. These seeds, when ready for planting, contain only the embryo and big cotyledons in which digested

**Nearly all of this lima bean seed is cotyledon. The embryo is only the curved root, stem and leaf at the upper edge.**

food is stored. Other seeds contain small cotyledons and a considerable amount of starchy endosperm which the cotyledons will use after the seed is planted.

Seeds that have big cotyledons and almost no endosperm usually germinate rapidly, because the cotyledons do not have to digest the starch before they can feed the embryo. Seeds that have small cotyledons and a quantity of starchy endosperm often germinate slowly, because the cotyledons still have to work to feed the embryo.

To see how seeds differ in this respect, put a few drops of water in a small vial and add an equal number of drops of tincture of iodine. Now open a lima bean seed and cut a corn grain in two lengthwise. Add a drop of iodine solution to the exposed section of each of the seeds. You can see the section of corn quickly turn dark blue, but the bean does not. The part of the corn grain that turned blue contained starch. Iodine turns dark blue when starch is present. The bean, however, does not show this color change because it cotyledons, which nearly fill the whole bean, have digested the starch and converted it into another form of food.

Try the starch test with a number of other seeds. Open them to expose the inside of the seed, then put a drop of your iodine solution on the exposed part. Blot them after testing to remove the excess iodine. Those that show a definite blue color have starch present; those that do not turn color probably have used up most or all of the starchy endosperm. What do you find when you make the test with a sunflower seed, a horsechestnut, a peanut, and a grain of wheat?

When the cotyledons of plants such as the peanut use up their starchy endosperm, they convert it to oils. Open an unroasted peanut, press half of the seed against a piece of paper, then hold the paper to the light. Can you see an oily spot where the cotyledons touched the paper? Can you find the tiny embryo at one end of the peanut half? If you do not see it on the half that

you pressed against the paper, look at the other half. It will be on one or the other.

When a fruit containing seeds is ripe, the seeds are mature. The cotyledons have stored what food they need and the seed itself ceases nearly all activity. The seed coat hardens, and the entire seed becomes dormant. Scientists do not know just why the embryo stops growing at this stage. Perhaps it is because the water supply to the growing seed is cut off. Perhaps it is because of some little known and understood chemical signal produced by either the parent plant or the embryo. At any rate, when the seed is mature, the embryo becomes quiet. It is *not* dead, and it is *not* asleep; it is simply dormant or resting. When conditions are right for it to resume growth, it will do so.

This is perhaps the most wonderful thing about seeds. Although they are dormant, they contain all that is necessary for a new plant. Inside them is a small embryo with new leaves and a new root. Around the embryo is a food supply. Embryo and food are surrounded by a weatherproof, protective covering. This covering may be hard and thick like a nut, fleshy like an apple, or thin and transparent like a bean. In this form the seed can rest for many years, waiting for just the right moisture and temperature conditions. Then it will grow into a plant very nearly like its parent.

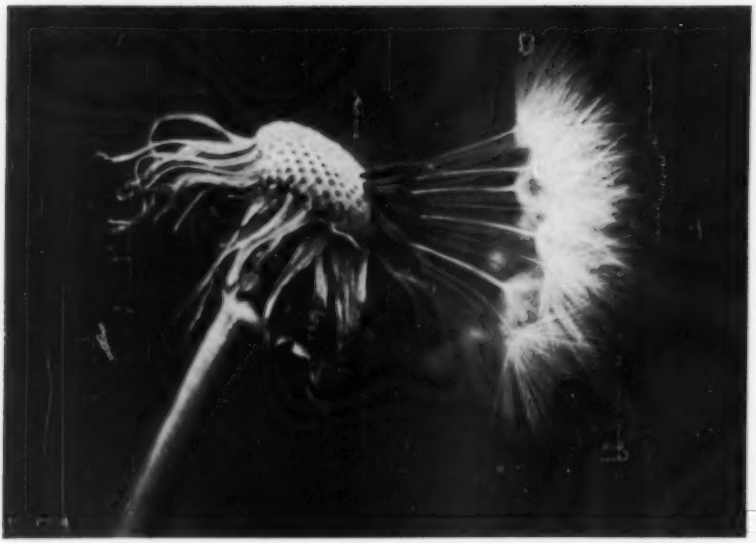
## HOW SEEDS TRAVEL

Seeds would not grow very well if they were deposited only under the parent plant, because they would have to compete with the parent for water, light, and minerals from the soil. It is much more advantageous for any species to be able to scatter its seeds far and wide so they will have every opportunity to find the optimum germinating conditions. A variety of interesting means for scattering seeds have evolved. You can study most of them right around home or school.

### Airborne seeds

If you live near a cottonwood tree, or a grove of cottonwood trees, you can see how effective a tuft of silky fuzz is for carrying seeds on the wind. Seeds that have a tuft of fuzz fall to the ground very slowly and the slightest breeze has a chance to carry them far away before they strike the soil. Some airborne seeds can travel many miles before landing.

Thistle, milkweed, Indian hemp, cottonwood, cattail, and willow seeds have tufts of silk that help to carry them far and wide. Willows have such small and delicate seeds inside their tufts of silk that they soon die if they do not lodge in a place favorable for germination. Most other seeds carried by tufts of silk are hardier and can stand many days of unfavorable conditions for germination.



Single-seeded fruits of dandelion, each with its fuzzy parachute ready to be blown away.

You can try an experiment to see which of these airborne seeds is the slowest to descend. Get some of each kind and put them in a box. Because all of these seeds do not mature at the same time, you may need to collect a number of kinds during the year and save them for your experiment. Collect cottonwood seeds in late spring, and the others in late summer or early autumn. Take the box of seeds to the top of a stepladder in a room where there are almost no air currents. One by one, drop the seeds and time each to see how long it takes it to reach the floor.

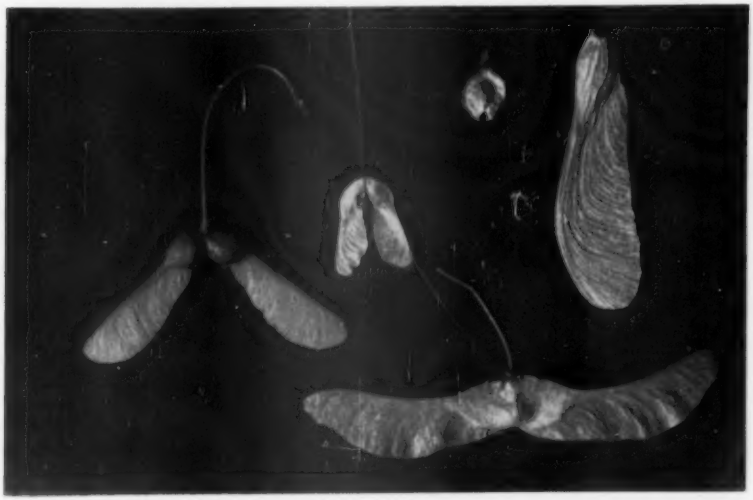
Most airborne seeds are carried less efficiently than milkweed, willow, or cottonwood. They have smaller tufts of fuzz, or wings to carry them. The seeds of many of the composites such as dandelions, asters, and goldenrods, are enclosed in a tiny hard shell with a cluster of hairs at one end. Each tiny floret of the composite family makes only one such fruit, but many fruits, each with its single seed, ripen on a single flower head. The dandelion has its tuft of hairs on a slender stalk. If you pinch a dandelion blossom in two, you can see the ring of tiny white hairs just above each

ovary. Can you see the short stalk that separates this ring of hairs (called the pappus) from the ovary? When the dandelion seed ripens, this stalk lengthens and lifts the pappus high above the seed to form a miniature parachute.

Look for a similar parachute on goatsbeard or wild salsify, a flower that grows along the roadside and resembles a very tall dandelion. Its parachute is lacy and beautiful as well as efficient.

Maples are probably the best known plants whose seeds are enclosed in a winged ovary. The ovary of the maple flower is a double one, with one ovule in each chamber. If you look at the maple flower in early spring, you can see the two stigmas and the winged ovary in which the seeds will develop. Watch how the stem of the flower elongates, and the wings become enlarged as the seed matures. Finally, the wind loosens the fruits with their seeds and they come spiralling to earth. Many land where they cannot grow—in the street, on the sidewalk, on roofs of buildings, or in gutters. Others sift down between the sidewalk and the lawn, into the grass, or under shrubs, and germinate.

Collect some maple seeds and compare the efficiency of their wings with that of the tufts of silk on milkweed or cottonwood. Which enables the seed to travel further?



Some air-borne fruits: left to right, top, sycamore maple, red maple, American elm, silver maple; bottom, right, Norway maple.

Winged seeds are also to be found on ash, tree of heaven, catalpa, elm, birch, tulip tree, and nearly all the conifers. The conifers open their cone scales when the weather is dry and out tumble the seeds, each with its fragile, yet efficient wing. Round and round these seeds spin as they fall, and farther and farther the wind carries them with each spin. Collect some seeds of local conifers (if you can beat the squirrels to them) and compare their falling rates with those of elm, or maple, or tree of heaven.

Basswood seeds grow from a leaf-like blade that remains suspended on the tree long after the leaves have fallen. The fruits are little downy balls, about cherry-pit size, each containing one or two seeds. When the blade that supports them loosens from the twig, it whirls its way to earth like a propellor or parachute, landing the seeds some distance from the tree.

Catalpa seeds grow tightly packed in a long, slender pod. Open a pod and count the seeds inside. There are more than you would think at first glance! Every seed has a wing on each side. When the pod finally splits, these seeds may spin and tumble a long way before they settle to the ground.

A few trees bear their seeds in thin, papery pods that drift and tumble in the wind. The Judas tree or redbud is one. The wind rolls and tumbles these seed pods across a snow surface for hundreds of feet before they come to rest in a fence-row or against a shrub. Black locust is another whose pods feel the force of the wind as they fall. Honey locust, however, has rather heavy pods, and although they turn and twist as they fall, they do not drift so far from the tree as the lighter, thinner pods of black locust and redbud.

## Hitchhiking seeds

In the fall hundreds of hitchhiking seeds are waiting knee-high for a furry or clothed passer-by on whom they can hitch a ride. When you pick them off and toss them on the ground before you enter your home, their hitchhiking habits have served their purpose—to scatter the seeds far and wide.

Look closely at a burdock. Its fruit is really a cluster of smaller fruits, each with a single seed and a ring of short fuzz at one end. The seeds travel in a prickly basket, because the outermost flower parts (called the *involucre* in composites) are all hooked at their tips. When you brush against a burdock, the involucral hooks catch on your clothing and pull off a whole basket of seeds. You may even be taking along a small brown moth, too, for its caterpillar often lives amid the cluster of fruits.

The seed of bidens is imbedded in a tight cover with two barbed

Some hitch-hiking fruits and seeds from field and hedgerow. How many can you pick up in a walk through a weedy field?

prongs at one end. These prongs give bidens its common name of pitchforks. You can see evidence of these barbed prongs even on the flower of bidens. Bur marigold is another name for this hitchhiker.

Avens looks like a small burdock, but unlike the burdock its seeds are equipped with individual hooks. When you brush against this hitchhiker, you seldom leave with only one seed in your clothing. You will usually pull off most of the seeds on one fruiting head.

There are many other efficient hitchhiking seeds. To see just how many and what different kinds there are, walk through a weedy field in the fall dragging an old piece of soft white cloth. The seeds you catch will show up well against it. Burlap makes an even more effective catcher of seeds, although they do not show up so well against the brown color. Look at your catch under a magnifier to see what makes the hitchhiking seeds so effective. On some you may find barbs, on others hooks, and on still others just fuzz that adheres to clothing.

## Seeds that are eaten

Birds are among the best of sowers, not because they purposely scatter seeds, but because they drop

many seeds where they roost. Some seeds pass right through the digestive tract of birds without being damaged. The birds' droppings may contain many seeds that germinate where they fall.

Many birds feed on staghorn sumac fruits in winter. The red fruit clusters of sumac are familiar to anyone who has hiked or driven through the countryside. Inside each red fruit is a round seed that is hard enough to withstand the grinding and churning of a bird's digestive tract. In fact, the outside of this seed is so hard that it germinates better if it is first scratched or nicked so water can seep into it.

Birds that eat sumac fruits usually rest in a hedgerow after feeding, and it is there that they drop the seeds along with their excrement. That is why sumac so often grows along hedgerows along with many other plants spread by birds.

Some other seeds that are hard like sumac, and usually pass right through birds' digestive tracts are poison ivy, privet, honeysuckle, grape, and several species of dogwood and viburnum. When these seeds are scratched or nicked, as they often are in birds' gizzards, their germination is hastened.

Foxes eat grapes, cherries, and berries of many kinds as well as mice and an occasional young bird. Fox droppings nearly always contain seeds that will germinate when conditions of moisture and temperature are right.

## Rodent hoarders and buriers

Chipmunks, squirrels, and mice hoard and bury untold numbers of seeds of many kinds. Some of these are eaten, but some germinate if the rodents do not eat them or cannot find them.

Gray squirrels are nearly as efficient as birds in their seed-planting. In the fall, squirrels bury seeds of many kinds including acorns, hickory nuts, walnuts, maple seeds, and some seeds from smaller herbaceous plants. Although they have a keen sense of smell and can locate many of the seeds they plant, gray squirrels probably miss more than they find. Those that are missed usually germinate where they were buried.

Red squirrels also feed on acorns, nuts of various kinds, and the seeds of many trees and shrubs. Often the seeds they store will germinate when moisture reaches their hiding places.

## Pop-out seeds

Witch hazel has evolved a way to scatter its seeds that does not depend upon birds, barbs, or breezes. As it dries, the open-ended container slowly squeezes the seeds until they pop out, sometimes for a distance of several feet. You can see and hear witch hazel pop its seeds if you collect branches bearing unopened fruits in September and keep them in a warm school room. Occasionally, one will pop all the way across a room, much to the

delight of the pupils.

Jewelweed or touch-me-not is another seed popper. In late summer its fruits hang like miniature cucumbers from the underside of its stems. They seem to bulge from the two or three large and tasty seeds inside the fruit. If you try to pick one of these fruits, you must do it carefully, for a ripe fruit will split open at a touch, scattering the seeds several inches away.

If you can cup your hand around the ripe fruit of a jewelweed and catch the seeds as they pop out of their container, you will have a tasty treat, for the seeds are good to eat. They taste a little like black walnuts.

### Fall-away seeds

Some seeds are not edible, nor do they sail with the wind. They have no spines for catching in fur or clothing. Their only means of spreading is to roll or tumble on a hillside. Osage orange is an example. The fruit is baseball-sized, lumpy and yellow, and its juice is sticky white. Almost no animal except young boys take an interest in them. The fruits can roll quite far on sloping ground, but boys can throw them even farther.

The cocoanut fruit is one of the world's largest. It is heavy, hard, and cannot be carried by wind or small animals. When it falls into water, however, it floats, and may be washed and blown out to sea. Salt water seems to have little effect on it, but when it finally washes up on a distant shore, scratched by sand and coral, the seed it contains may germinate. The cocoanut, almost the biggest and heaviest of seeds, may hold a record for distance traveled.

## GERMINATION OF SEEDS

### Absorption of water

When seeds are scattered, whether by wind or animals, they are usually dry inside. As the stalk that supports them in the ripening ovary ceases to conduct water, in the fall, beans, peas, nuts, and the fruits of plants in hedgerows and fields become extremely dry, and remain unmoistened throughout most of the winter.

Even a seed such as the cocoanut is contained inside a hard fibrous cover. It can float for miles in sea water, and the seed inside will absorb almost no moisture. Later, when the fibrous coat is worn away, the seed may absorb water and sprout.

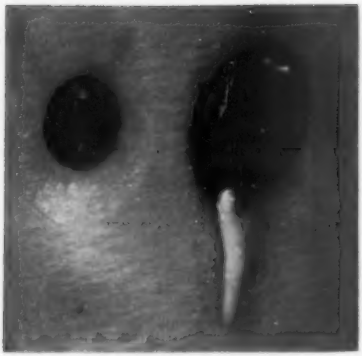
To appreciate the changes that take place in the cotyledons of a seed during germination, examine a dry bean. Split it and try to press a knife blade into the dry cotyledon. How hard it is! Now put some beans to soak overnight. The next day, open one and again press the point of a knife into the cotyledon. Notice how much softer the cotyledon is.

The absorption of water not only soften the food inside, but is accompanied by marked swelling of the seed. This swelling exerts sufficient force to burst even the toughest seed coat. Put some dried peas or beans into a small bottle with a screw top. Fill it as full as you can by shaking and pressing the seeds down in the jar. Punch a few small nail holes in the cap and screw it tightly into place. Turn the bottle on its side in a dish of water and let it stand for a day. What changes can you see inside the bottle? If the bottle has not been broken by the force of the swelling seeds, at least you can see that they have been squeezed together with tremendous pressure and tightly flattened against each other and against the sides of the container. The tales about ships having been sunk by swelling grain cargoes certainly have basis in fact. If a leak in the hold of a ship should let water into a full load of dry grain, the load could swell with almost unbelievable force. The sides of a ship would be no match for such conditions.

Seeds not only gain in size as they absorb water, but they gain in weight. Weigh a handful of dried

A small jar filled with dried peas and kidney beans. The top has been punctured to admit moisture.

After soaking for a few hours, the dried peas and kidney beans in this bottle swelled tremendously.



The honey locust seed on the right was nicked with a file before planting. The one on the left was not.

lima beans or navy beans, then put them in a dish of water for a day. At the end of one day, pour off the water, dry the seeds on paper toweling, and weigh them again. What is the percentage of their gain in weight? Try the same thing with corn, rice, wheat, and peas. Do they all gain about the same percentage in weight? Which seeds gain the most?

Some seeds do not absorb water readily unless their seed coat is worn, scratched or nicked. Unless they are exposed to the weather for several months and have their seed coats bruised or nicked, the shiny, hard honey locust seeds seldom germinate.

You can see this for yourself if you get some honey locust pods in winter, break them open, and take out the seeds. Stuff paper toweling into a glass tumbler, fill it one-third full of water, and insert some of the seeds along the side, between the glass and the wet toweling.

Scarify (scratch) each seed in a second lot by holding the seed between your fingers and running a file across it several times. Put the second lot in a tumbler arranged like the first. Examine the seeds each day for several days; what differences in the two lots of seeds can you observe?

## Growth of the embryo

When the seed has absorbed considerable water, and when the temperature is right, the embryo will resume its interrupted growth. Scientists are not certain why the embryo resumes growth. Temperature and moisture are certainly two of the most important factors.

To understand what changes take place in the embryo as it resumes growth, you should first know what the embryo in a seed looks like, where it is located, and what its parts are. The lima bean embryo is an excellent one for classroom study, because it is easily obtained, and is large enough for pupils to see clearly.

Look at some dried lima beans, or navy or kidney beans. Can you see that there is a hard shiny transparent covering on the seed? This is the seed coat, formed by the coverings of the ovule when it was in the ovary of the flower. The seed coats

A lima bean embryo separated from the attached cotyledons. Most of what you see is root and leaves.

of other seeds are not transparent, and are often much thicker than those on the bean.

On the inside curve of the seed there is a scar called the *hilum* (high'-lum). This is the scar left by the stalk of the ovule. The beans were connected by this stalk to the margin of the pod. The pod was the ovary in which the ovules (beans) grew.

Near one end of the hilum is a tiny scar, the *micropyle,* where the pollen tube that helped fertilize the egg entered the ovule (see page 8). This micropyle closes almost completely in most seeds, but remains on others as a tiny scar.

In sunflower seeds, the micropyle is at the pointed end of the seed. If you hold a sunflower seed under water and pinch it, you can see bubbles of air come out from the micropyle. Can you see bubbles from the micropyle of a squash seed, a pumpkin seed, or a locust seed? In which of the seeds you examine has the micropyle disappeared? In which ones can you still see it? Remember that the largest scar you see is the hilum. The micropyle will be only a tiny one.

Soak lima beans overnight before trying to split them to see the embryo. The picture at the left shows an exposed lima bean embryo. Notice the two tiny leaves at one end of the embryo, and the root-like structure (called a *radicle)* at the other end. Between these two structures the cotyledons are attached. The cotyledons in the bean occupy nearly all that you see except for the embryo.

When the embryo begins to grow, the radicle makes its way out between the cotyledons and downward. No matter how the seed is placed, the radicle will turn down as soon as it is out of the seed. Only a more moist area somewhere other than below the seed will make the radicle turn to the side, or up.

To see that this is true, get two pieces of window glass about six by eight inches. Cut two pieces of corrugated cardboard the same size and soak them well. On one of the pieces of cardboard lay a lima bean

with its hilum away from you. Put another with its hilum toward you, one with its hilum to the left, and one with its hilum to the right. Cover these with the second cardboard, put the glass on the outside, and hold the sandwich together with several rubber bands. Stand the package upright in a shallow container of water and leave it for a few days. When you open the sandwich, you can see whether the position of the seed has any effect on the direction of the radicle.

If all the beans seem to be germinating well, recover the seeds, turn the sandwich upside down and stand it in the water again. In about three days examine the position of the roots. Do they turn down toward the water, or have they kept growing in the same direction?

The cotyledons in seeds differ greatly in the manner in which they serve the embryo. In some seeds, the cotyledons remain underground and never become green. In others, the cotyledons are lifted by the stem of the young plant. Above the ground they become green and carry on photosynthesis for several days before the regular leaves take over and the cotyledons wither.

Navy beans carry their cotyledons up out of the ground, but corn keeps its single cotyledon underground. You can see this if you plant some navy beans in one pot of moist earth and some corn seeds in another pot. In addition to the fact that the bean has two cotyledons and the corn only one, notice that the beans germinate much faster than the corn seeds. Do you recall why? (See page 9.)

**This honey locust grew from the germinating seed shown on page 19. Note the cotyledons still attached below the true leaves.**

## One or two cotyledons?

Plants such as corn, wheat and other grasses, cattails, sedges, rushes, and lilies are called monocots because they have only one cotyledon in their seeds. Plants such as maples, roses, cherries, dogwoods, clovers, mints and dandelions are called dicots because they have two

**Both the new shoot and root are visible in this side view of a germinating corn grain.**

cotyledons in their seeds. You can easily see the difference between a dicot and a monocot in a germinating grass-seed mixture containing clover. Place a flat sponge on a plate of water so it will stay moist. Sprinkle a pinch of grass seed mixture over it. In a week to 10 days the grass and the clover will germinate and send up their first leaves. Notice that the leaves of the grasses are all pointed, and that only *one* leaf projects from each seed. When clover germinates, two tiny cotyledons show above the surface. Even if the two cotyledons had remained below the surface, *two* tiny leaves would soon appear above ground.

Children in the middle and lower grades become quite interested in such a sponge garden. The roots of the tiny plants will grow downward into the recesses of the sponge and support the tops for a number of days, especially if an empty aquarium or wide-mouthed jar is inverted over the germination sponge to keep the tops of the young plants moist. If a tiny bit of plant food is added to the water, this *lawn* can grow successfully for many days. Perhaps the children can even mow their lawns with scissors when the turf gets too high.

As the cotyledons nourish the growing embryo, their own stored food supply diminishes. When the embryo has gained enough in size and ability to make its own food, it becomes independent of the cotyledons. The cotyledons wither and fall away or are absorbed by the growing plant.

You can try a simple test to see the effect of the cotyledons in feeding the embryo of a seed. Soak some corn seeds overnight and then plant them in soil where it is warm. Moisten them each day to make them germinate as soon as possible. On the third day, dig up one of the corn seeds and cut it in half. Test its stored food with the iodine solution described on page 10. Can you see an immediate dark blue color change in part of the corn grain?

The next day, dig up another corn grain and try the iodine test again. How does the amount of blue color material compare with that of the day before? Test the seeds daily until the leaves are an

inch above the soil surface. Can you see a gradual decrease in the amount of starch left in the seed as germination progresses?

You cannot make the starch test satisfactorily in seeds such as peas and beans because they have already converted the endosperm to non-starchy material by the time you plant them.

If the cotyledons of a plant such as a kidney bean are removed during the first through the fourth day after germination, the embryo usually does not survive. If the cotyledons are removed after the fifth day, however, the chances for survival are good; by that time the young plant is able to make its own food.

As you experiment with seeds of various kinds, observe the cotyledons and the way in which they help the young plant. They are one of the most important structures in any seed.

## The root

At germination, the radicle of the embryo pushes its way out through the seed coat and down through the soil to form the new plant's first real root. Its function is to hold the new plant in place, and to absorb water and minerals from the soil around it. When it first appears, the root gets its nourishment from the stored food in the cotyledon, but soon after it penetrates the soil, it begins its function as an absorbing organ. To help it, many tiny *root hairs* make their appearance near its tip.

To see what root hairs are really like, soak a small clay flower pot and invert it in a pan of water. Keep the water level below the rim of the pot. Along the shelf formed by the rim, sprinkle a few radish seeds as shown. To keep the germinating seeds moist, cover the inverted pot with a wide-mouthed jar or a plastic or glass food container. In a few days you will see the radicle appear, and in another day or two you will see a white mass of root hairs along it.

One scientist investigated the root hairs on a four months old rye plant and estimated that it had 14 billion root hairs! This meant that new root hairs developed at about 100 million per day!

Not all seedling roots have a cover of root hairs. Coniferous seedlings ordinarily have few or none. Some plants such as corn have root hairs when they germinate in moist air, but have very few when they germinate in nutrient solutions. Put some radish seeds in a shallow dish of water and compare the root hairs on their seedlings with those germinating on a moist pot.

Root hairs do not last long, but keep reforming near the tip of the roots. They may last a few days, but then die and are replaced by new hairs nearer the tip of the growing root. Their sole function is to help absorb water and food.

This radish seed germinated on the rim of a moist flower pot, and produced a dense growth of root hairs behind the root tip.

If you examine the root hairs under a microscope, you will see that each hair is an extension of one of the cells covering the outside of the root. Can you estimate the number of root hairs on a six-day-old radish root like the one shown on the opposite page?

In a radish plant, the root hairs may increase the absorbing surface

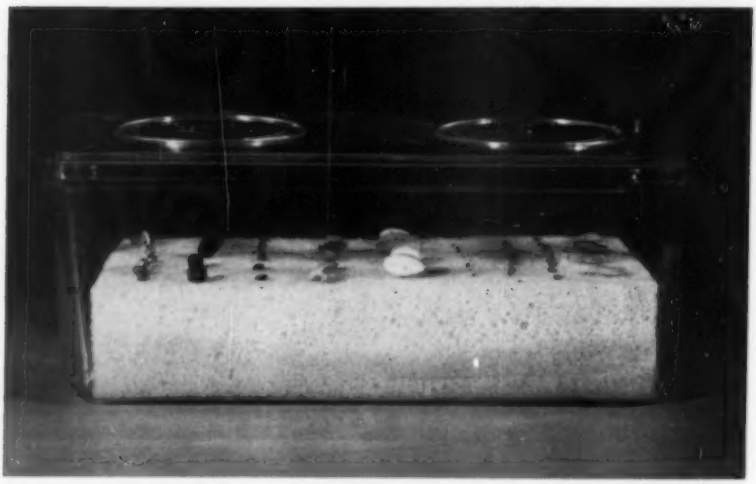
Secondary roots have begun to appear on this germinating squash plant.

of the root as much as twenty times.

When the primary root has grown long enough to support the new plant and absorb water and food from the soil, it often branches, sending secondary roots off in different directions. Not all plants develop extensive primary roots. Some retain the single primary root, which thickens and becomes a storage organ such as in the beet, the carrot, and the radish. Others such as grass develop very extensive fibrous root systems. One investigator found that the total length of roots on a young rye plant was nearly 400 miles! Think how efficient such a root system is for absorbing moisture and holding a plant in place.

Some seeds such as corn develop roots at some distance above the primary root. These are prop roots, and help to anchor tall corn plants in the soil. If you place some corn grains on a moist sponge and cover it with a transparent container, you will be able to see the small prop roots as they form above the point where the primary root emerges. Look for them on mature corn plants. They will grow out from the stem above the soil, and angle down into the soil several inches from where they begin.

On a moist sponge, or in pots of soil, plant a number of different seeds from around your home or school and compare the length of



Moisten a sponge and put it in a covered dish. Put rows of various seeds on it and you can observe several rates and ways of germination.

time for germination, the changes in the seed as germination proceeds, and the manner in which the root emerges, shows root hairs, and develops secondary roots. Where does the root first make its appearance in a sunflower seed, in a squash seed, in a maple seed, in a grass seed, and in a pine seed?

## The leaves

You saw the leaves of a lima bean or navy bean seed when you soaked and opened them to observe the embryo inside (page 20). These tiny leaves of the dicots have veins and all the tissues necessary for carrying on their foodmaking function as soon as they are above ground and in the sunlight. When they begin to make food for the new plant, there is no need for the accessory cotyledons, so they vanish.

When you plant seeds of different kinds, watch for the first true leaves to emerge. First you will see the obvious difference between monocots and dicots (one leaf as compared to two). Then you will notice that the leaves seem to stay at the tip of the stem as it grows longer. What you cannot see is that a small growing point at the base of the first leaves keeps right on growing even after the first leaves are almost mature. This growing point is the most active part of the plant above ground, just as the root tip is the most active part below ground.

## The stem

The stem on an embryo within the seed is short and not very well defined. It is between the root-like radicle and the young leaves. The cotyledons are connected to the embryo at the stem.

When the radicle has penetrated the soil, and the leaves begin to push upward, the stem makes rapid growth. Some seedling stems lift their cotyledons right out of the ground, along with the new leaves. Most stems, however, grow upward from the buried cotyledons and carry with them only the first of the true leaves.

Stems on young seedlings are often green. They carry on photosynthesis just as a leaf does. Later, when the leaves are able to make food for the entire plant, the stem loses its green color and becomes only a supporting, food- and water-conducting, and storage organ.

Only the tip of the stem is important in making the plant grow taller. You can test this by putting some India ink marks on the stem of a seedling, spacing the marks one-quarter inch apart all the way up the stem to its tip. Do the lower marks get farther apart as the plant grows? Do you have to keep adding new marks at the top? Where does it appear that most of the lengthening of the stem takes place—all along the stem, or at its tip?

Seed coats, cotyledons, primary root, secondary roots, and stems are all visible in this germinating lentil. Put some on a moist sponge and watch their progress.

## FEW OR MANY SEEDS?

Some plants produce thousands upon thousands of seeds, and others produce only a few. Those that produce only a few seeds may be very successful at scattering their seeds where they will germinate, so they do not need to broadcast tremendous numbers. The nut trees, for example, are almost certain to have many of their seeds actually planted and left in the soil by squirrels. Germination is easy for seeds such as these.

A birch tree, however, usually grows in a forest where many plants compete for water, light, and food. Very few seeds germinate in places where they have a good chance of growing to mature trees. For this reason, birch trees have evolved a tremendous seed production. They scatter tens of thousands of seeds to the wind. A few are lucky; the rest never mature.

To see how many seeds some plants make to insure that their species will continue, get a red-root pigweed plant in autumn and bring it into the classroom. Spread a sheet of white paper on a desk and tap the plant on the paper several times to knock off the seeds. You will knock off the brownish husks, too, but you can tell them from the shiny black seeds. Try counting the seeds from a single plant. What is your estimate, and how did you arrive at it? Did you count every single seed, or did you estimate after counting one pile of a hundred and comparing it with what was left?

Perhaps you can estimate the number of pigweed seeds produced in a single field by counting the seeds from one plant, and then estimating the number of plants in the field. You can also do this for dandelions, and a number of other weeds. Can you see why weeds are so successful in quickly taking over an uncultivated field?

In learning about the numbers of seeds produced by various plants, compare the seed counts of a watermelon, an oak tree, a milkweed plant, a cattail, a dandelion, an elm tree, and a maple tree. Can you see any relationship between the effectiveness of the seed dispersal and the number of seeds produced? How does the cattail fit your idea of this relationship?

Some plants do not depend upon their seeds for spreading the species. Strawberries have developed runners, potatoes have enlarged underground stems with buds that grow new plants, poplar tree roots send up new shoots here and there and stems of witch-hobble and raspberry bushes touch the ground and take root. How many other vegetative means of reproduction can you find?

## SEEDS THAT WE USE

### Food

A surprising number of foods and spices in almost any American kitchen come from seeds. Some are cocoa, coffee, oatmeal, cornflakes, rice, puffed rice, pepper, mustard, beans, peas, peanuts, butter, cocoanut, cornstarch, and almost all baked goods.

Peas, beans, rice, coffee, peanut butter and pepper make use of the whole seed; other foods make use of only part of the seed. Cornstarch, for example, is the starchy endosperm of the corn grain. Flour comes from the endosperm of wheat and buckwheat. Peanut oil is squeezed from the cotyledons of peanuts.

Some seeds are used as food for animals other than man. Corn, oats and barley are basic foods for many farm animals. Sunflower seeds are fed to birds in winter. Rape, millet and canary seed are raised as food for pet birds.

Wild animals depend upon many of the seeds that grow in fields and forests. Birds, foxes, raccoons, opossums, meadow mice, and rats eat vast quantities of seed, both cultivated and wild. Even a number of insects live on seeds. The larvae of many beetles and moths spend their entire lives inside seeds.

### Other uses of seeds

The cotton seed is one of the most important seeds not used entirely for food. The tuft of silky fibers that helps to carry the seed forms the raw material for cotton cloth. The cotton seed itself is pressed to make cottonseed oil, an important material for oleomargarine, soap, and salad oil.

Flaxseed is the source of linseed oil, the base for most house paints. Tung oil comes from the nuts of tung trees; it is used in varnishes and quick-drying paints. Castor beans produce castor oil, most important in cosmetics and lubricating oil for high-speed engines, but also used in medicines. Soybeans are important not only as food, but for the plastics industry. We would live in a much different world if seeds were used only for food!

In your observations of and experiments with seeds, you will learn about many things not described in this Leaflet. You will learn that some seeds mold when too much water is present. Others need considerable water for their germination. You will learn that not all seeds will germinate, no matter how careful you are with them. You will find an amazing variety in size, shape, number, germination time, and use of seeds. Keep a record of what you learn from your observations. It will make the study of seeds more fun and more worthwhile.

## SOME HELPFUL REFERENCES


BROWN, ANN, HOW DOES A GARDEN GROW?, *Dutton, New York, 1958. 46 pages.* A story of how Alice and Emily planted a flower and vegetable garden, tended it, and finally had both flowers and vegetables for sale. Primary, intermediate.

CUTLER, KATHERINE, THE BEGINNING GARDENER, *Barrows, New York, 1961. 165 pages.* A guide book for the child gardener and his teacher. Includes directions for soil mixtures, planting seeds indoors, and for planting vegetable, herb, and wildflower gardens. Intermediate, upper.

LANE, FERDINAND, ALL ABOUT THE FLOWERING WORLD, *Random House, New York, 1956. 136 pages.* Contains interesting chapters on the flower, pollination, and seeds and their ways. An occasional error does not seriously depreciate the value of this handy book for elementary pupils and their teachers. Intermediate, upper.

SELSAM, MILLICENT, PLAY WITH SEEDS, *Morrow, New York, 1957. 93 pages.* Interesting and well-written descriptions of the development and uses of seeds. Contains numerous simple experiments and activities with common seeds. Intermediate, upper.

SELSAM, MILLICENT, SEEDS AND MORE SEEDS, *Harper, New York, 1959. 59 pages.* A simple story of Benny's first experiments with seeds, and what he learned from them. Primary.

STEFFERUD, ALFRED, THE WONDERS OF SEEDS, *Harcourt, Brace, New York, 1956. 119 pages.* An interesting and authoritative book about how seeds are made, how they sprout, seed *packages,* how seeds are scattered, and seeds as food. Includes activity suggestions, as well as information on the work of plant breeders. Intermediate, Upper.